Report No. 8926-172

Material - Nickel Base Alloy - Hastelloy R-235
(Haynes Stellite Co.)

Spot Weld Strengths

(An Abstract Report)

Abstract:

Cleaning procedures, spot welding parameter survey data, and data indicating strengthening resulting from cold work and aging are presented with respect to 0.020" and 0.040" thick Hastelloy R-235 nickel base alloy. The following data, representative of the use of optimized cleaning and spot welding procedures, compare the effects from cold work and aging treatments used to strengthen 0.020" thick Hastelloy R-235 sheet.

Material Condition	Tensile Shear Strength	Cross Tention Strength	T.S.1 C.T. Ratio
Mill anneal,* weld	810 lb/spot	87 lb/spot	.11
Mill anneal, weld, age**	587	77	.13
10% cold work, weld**	1102	659	.60
10% cold work, weld, age**	683	207	.30

* 1975°F, water quench
** 1550°F, 2 hours, air cool

Reference: Alesch, C. W., "Material - Nickel Base Alloy - Hastelloy R-235 (Haynes Stellite Co.). Spot Weld Strengths (An Abstract Report)", General Dynamics/ Convair Report 8926-172, San Diego, California, 19 April 1963. (Reference attached).

Report No. 8926-172

Material - Nickel Base Alloy - Hastelloy R-235
(Haynes Stellite Co.)

Spot Weld Strengths

(An Abstract Report)

Reference: Vermilyea, E. J., Green, E. D., Carr, W. L., Margitan, E., "Fabricability of Materials R-235, L-605, Rene 41, M-252 and J-1650 as Pertaining to Part No. 8-26054," General Dynamics/Convair Report AMR-PR 889, San Diego, California, April 1961.

Cleaning Method

Haynes Stellite Co., Hastelloy R-235 0.040" thick, mill annealed (1975°F) sheet was cleaned, in preparation for spot welding, according to the schedule given in Table 1. In the cleaning tests, a satisfactory range of immersion times in the hydrofluoric acid - nitric acid pickling solution was sought. Two criteria were used to judge pickling solution times; (1) the incidence of surface roughness upon and intergranular corrosive attack within the sheet, and (2) the tensile shear and cross-tension strengths of spot welds. The spot welding schedule used is given in Table 2. No surface roughening or corrosive attack resulted from 1 to 5 minutes pickling of annealed Hastelloy R-235 in the hydrofluoric acid - nitric acid mixture. The results of spot welding tests are shown in Table 3. These tests showed that weld strengths optimized with respect to strength and range of strengths in individual spot welds when 1 to 2 minutes of immersion in the pickling bath was used for welding preparation.

Supplementary cleaning tests with 0.020" thick mill annealed (1950°F, water quenched) Hastelloy R-235 which was aged at 1500°F for 2 hours showed that the material was subject to intergranular corrosion attack when cleaned according to the Table 1 schedule.

Spot Welding Parameters

Using the cleaning schedule established as described, and the Table 2 spot welding schedule as a basis, the effects of variations in electrode pressures, welding currents, and electrode radius upon spot weld strengths were determined with mill annealed 0.020" and 0.040" thick Hastelloy R-235 sheet. The results of these tests are given in Table 4 and show

1. Relatively high electrode pressures are required to forge spot weld nuggets of R-235. Tests showed that spot welds in 0.020" thick material optimized at 2000 pounds pressure. The higher

pressures resulted in larger nugget diameters which tended to increase tensile-shear strengths; but these greater pressures reduced interface resistance which decreased nugget penetration and resulted in low cross-tension strengths.

2. As the welding current (amperage) was increased, the tension-shear and cross-tension strengths both increased. Nugget diameters were not significantly changed but nugget penetration increased. The high electrode pressure used optimized tensile-shear strength but did not optimize the tensile-shear to cross-tension strength ratio and this indicated need for lower welding pressure.

3. Of the three electrode radii used, the relatively flat electrodes produced higher tensile-shear and cross-tension strengths.

Effects of Heat Treatment and Cold Work on Weld Strengths

Table 5 shows results obtained by varying the sequencing of welding within the heat treating sequence. These results show that optimum spot weld strengths are realized with annealed material (0.040" thick Hastelloy R-235). Welding followed by aging results in reductions in cross-tension strengths which result in tensile-shear to cross-tension ratios of 34% which contrast with the 48% optimum observed with annealed material. Aging followed by heat treatment results in reduction of tensile-shear strength from 2100 lb. with annealed and welded material to 1964 lb. with the aged material. Aging followed by heat treatment, however, tends to preserve ductility as the 46% tensile-shear to cross-tension strength ratio indicates.

Table 6 data compares weld strengths obtained with cold worked and non-cold worked 0.020" thick Hastelloy R-235 sheet when aging is omitted and when welding just precedes aging. These data show that optimum weld strengths are developed in material which is 10% cold worked, welded, and left unaged.

Prepared by C. W. Alesch
19 April 1963

Table 1

Cleaning Method for Annealed R-235

Operation	Cleaning Components	Temp °F	Time (Min.)
Vapor Degrease	Stabilized Trichlorethylene (per Mil-T-7003)	180 - 195	1
Alkaline Clean	Oakite 61A, 5-6 ounces per gallon	150 - 180	5
Hot Water Rinse	Steam Condensate	130 - 180	1
Pickle	1.5-20% Hydrofluoric Acid, 25-35% Nitric Acid	Room Temp.	Varied
Water Rinse	Tap Water	Room Temp.	1
Dry	Hot Air	120 - 150	2

Table 2

Welding Schedule for Annealed R-235

Amperes	9100
Weld Time	9 cycles
Weld Impulses	3
Weld Pressure	4000 lb.
Preheat Amps	5600 amps
Preheat Impulses	3
Cool Cycles	0.5
Squeeze Cycles	21
Hold Cycles	24

Table 3 **Cleaning Evaluation of Annealed R-235 For Resistance Spot Welding**

Coupon No.	Cond.	Gage inches	Tensile-Shear (lb.)	Cross-Tension (lb.)	Averages			Range	
					Tensile -shear (lb.)	Cross Tension (lb.)	C.T. T.S. %	Tensile Shear (lb.)	Cross Tension (lb.)
Group I.	Alkaline Bath only								
1	Ann.	.040"	2050	1500	2162	1214	56.0	170	610
2	"	"	2220	+700					
3	"	"	2150	890					
4	"	"	2175	1125					
5	"	"	2215	1340					
Group II.	Alkaline Bath and 1 Minute in HF & HNO_3 Pickle								
6	"	"	2050	1095	2092	1028	49.2	100	280
7	"	"	2055	*					
8	"	"	2090	905					
9	"	"	2115	1185					
10	"	"	2150	925					
Group III.	Alkaline Bath and 2 Minute in HF & HNO_3 Pickle								
11	"	"	2150	+820	2136	1163	54.5	75	350
12	"	"	2130	960					
13	"	"	2175	1310					
14	"	"	2125	1120					
15	"	"	2100	+755					
Group IV.	Alkaline Bath and 5 Minutes in HF & HNO_3 Pickle								
16	"	"	1995	855	2031	1100	54.2	180	425
17	"	"	2155	1285					
18	"	"	1975	1175					
19	"	"	+1485	905					
20	"	"	2000	1280					

* Destroyed in Testing

\+ Nugget Expulsion (Not used in averages)

Table 4

R-236 Resistance Spot Welding Amperage, Electrode Pressure and Radius Studies

CONDITION	GAGE (INCHES)	MACHINE SETTINGS: AMPS	TIME CYCLES	ELECTRODE PRESS. (LB)	NO. OF WELD IMP.	ELECTRODE: RWMA CLASS	POINT GEO. BOTH ELECS.	AVE. NUGGET DIA. (INCHES)	TENSILE SHEAR (LB)	MIN. TENSILE SHEAR REQ'S MIL W 6858 (LB)	CROSS TENSION (LB)	$\frac{CT}{TS}$ %	AVERAGE: TENSILE SHEAR (LB)	TENSILE SHEAR REQ'S MIL W 6858 (LB)	CROSS TENSION (LB)	$\frac{CT}{TS}$ %
Electrode Pressure Study																
ANN.	.020"	8400	9	2000	3	III	6" R		630		434	70				
ANN.	.020"	8400	9	2000	3	III	6" R	0.105	740	530	280	38	701	655	364	52
ANN.	.020"	8400	9	2000	3	III	6" R		724		377	52				
ANN.	.020"	8400	9	2500	3	III	6" R		654		160	25				
ANN.	.020"	8400	9	2500	3	III	6" R	0.150	650	530	120	18	659	655	133	20
ANN.	.020"	8400	9	2500	3	III	6" R		674		120	18				
ANN.	.020"	8400	9	3000	3	III	6" R		774		140	18				
ANN.	.020"	8400	9	3000	3	III	6" R	0.160	850	530	100	12	799	655	110	14
ANN.	.020"	8400	9	3000	3	III	6" R		773		90	12				
"	.020"	8400	9	3500	3	III	6" R		684		87	13				
ANN.	.020"	8400	9	3500	3	III	6" R	0.170	656	530	95	14	660	655	79	12
ANN.	.020"	8400	9	3500	3	III	6" R		670		67	10				
Amperage Studies																
ANN.	.020"	7700	9	3000	3	III	6" R		628		65	9				
ANN.	.020"	7700	9	3000	3	III	6" R	0.190	640	530	85	13	643	655	77	12
ANN.	.020"	7700	9	3000	3	III	6" R		660		82	12				
ANN.	.020"	8400	9	3000	3	III	6" R		630		91	14				
ANN.	.020"	8400	9	3000	3	III	6" R	0.160	644	530	108	17	648	655	104	16
ANN.	.020"	8400	9	3000	3	III	6" R		670		114	17				
ANN.	.020"	9100	9	3000	3	III	6" R		694		124	18				
ANN.	.020"	9100	9	3000	3	III	6" R	0.190	698	530	135	19	666	655	122	18
ANN.	.020"	9100	9	3000	3	III	6" R		696		108	15				
Electrode Radius Studies																
ANN.	.040"	9100	9	4000	3	III	FLAT		2050		1500	73				
ANN.	.040"	9100	9	4000	3	III	FLAT	0.180	2220	1460	700	31	2140	1800	1017	48
ANN.	.040"	9100	9	4000	3	III	FLAT		2150		850	40				
ANN.	.040"	9100	9	4000	3	III	6" R		1890		905	48				
ANN.	.040"	9100	9	4000	3	III	6" R	0.180	2036	1460	1185	57	2000	1800	1005	50
ANN.	.040"	9100	9	4000	3	III	6" R		2088		925	44				
ANN	.040"	9100	9	4000	3	III	4" R		1930		755	39				
	.040"	9100	9	4000	3	III	4" R	0.180	2010	1460	855	42	1990	1800	965	48
ANN.	.040"	9100	9	4000	3	III	4" R		2040		1285	63				

Table 5. Welding Conditions Study for Resistance Spot Welded R-235

Coupon No.	Gage Inches	Tensile Shear Results				Cross Tension Results				Cross-Tension to Tensile Shear Ratio
		Anneal Then Weld	Weld Then Age	Age Then Weld	Avg.	As Rec'd.	Weld Age	Age Weld	Avg.	
1	0.040	2050			2101	905			1010	48%
2	"	2090				925				
3	"	2115				1115				
4	"	2150				1095				
5	0.040		2290		2291		865		771	34%
6	"		2305				760			
7	"		2335				720			
8	"		2235				740			
9	0.040			1840	1964			940	898	46%
10	"			1990				955		
11	"			1940				870		
12	"			2085				825		

Table 6. **Tensile Results of Resistance Spot Welded R-235**

Coupon No.	Gage Inches	Tensile Shear Results					Cross Tension Results					Cross Tension to Tensile Shear Ratio	Standard Deviations	
		Anneal Then Weld	Weld Then Age	10% C. W. Then Weld	10% C. W. Weld Then Age	Avg.	Anneal Then Weld	Weld Then Age	10% C.W. Then Weld	10% C.W. Weld Then Age	Avg.		Tensile Shear	Cross Tension
A1	0.020	800				810	55				87	11%	44.7	27.2
2	0.020	740					110							
3	0.020	830					60							
4	0.020	820					97							
5	0.020	860					111							
B1	0.020		400			587		45			77	13%	232.3	29.9
2	0.020		736					86						
3	0.020		283					99						
4	0.020		697					110						
5	0.020		820					47						
D1	0.020			1120		1102			675		659	60%	23.6	16.6
2	0.020			1100					650					
3	0.020			1120					670					
4	0.020			1070					640					
E1	0.020				870	683				140	207	30%	203.8	59.4
2	0.020				716					250				
3	0.020				463					230				